Getting Started With GIS
Chapter 2

Information ordering: Lists and indexes

Organizing data and information
- Information can be organized as lists, numbers, tables, text, pictures, maps, or indexes
- Clusters of information called data can be stored together as a database
- A database is stored in a computer as files
- File systems are often hierarchical
The elements of GIS

Figure 2.1 The elements of a GIS. (1) The database (shoebox); (2) the records (baseball cards); (3) the attributes (the categories on the cards, such as batting average); (4) the geographic information (locations of the team’s stadium in latitude and longitude); (5) a means to use the information (the computer).

The GIS database

- A database handles information storage, retrieval and query
- In a database, we store attributes logically as column headers and records as rows
- The contents of an attribute for one record is a value
- A value can be numerical or text

Flat file database

<table>
<thead>
<tr>
<th>Record</th>
<th>Attribute</th>
<th>Value</th>
<th>Attribute</th>
<th>Value</th>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Attributes have units

The sign in New Cuyama displays population data.
The GIS database (ctd)

- Data in a GIS must contain a geographic reference to a map, such as latitude and longitude
- The GIS cross-references the attribute data with the map data, allowing searches based on either or both
- The cross-reference is a link or index

Cartography and GIS

- Understanding the way maps are encoded to be used in GIS requires knowledge of cartography
- Cartography is the science that deals with the construction, use, and principles behind maps and mapping
- A map is a depiction of all or part of the earth or other geographic phenomenon as a set of symbols and at a scale whose representative fraction is less than one to one

Geodesy: Models of the earth

The earth can be modeled as a
- sphere
- oblate ellipsoid (“spheroid”)
- geoid
- flat surface

The Flat Earth Society
Measuring the Ellipsoid

- Oblate ellipsoid predicted by Newton
- Existing triangulation along Paris meridian in France (Cassini-Prolate spheroid)
- French Academy of sciences sent expeditions to Lapland and Peru (now in Ecuador) to measure the length of a degree along a meridian
- La Condamine sent to Mitad del Mundo, Peru (Equador) (Bouguer, 3 deg.)
- Moreau de Maupertuis sent to Tomio River Valley, Finland

Measuring the Ellipsoid (ctd)

- Maupertuis reported a meridian degree as 57,437.9 toises (1 toise = 1.949 m)
- Meridian degree at Paris was 57,060 toises
- Concluded Earth was flatter at poles
- Measures were erroneous but conclusions were correct
- Published as “La Figure de la Terre” (1738)
La Figure de la Terre (1738)

Maupertuis's Map
- River Tornio in modern Finland
- 14.3 km base line laid out on the ice
- Surveyed line by triangulation
- Anders Celsius, Swedish physicist, was a member, and had suggested solution by direct measurement

Earth as Oblate Ellipsoid

The spheroid and ellipsoid
- The sphere is about 40 million meters in circumference.
- An ellipsoid is an ellipse rotated in three dimensions about its shorter axis.
- The earth's ellipsoid is only about 1/298 off from a sphere (difference in circumferences is about 42km)
- Many ellipsoids have been measured, and maps based on each
- Examples are NAD27, WGS84 and GRS80
- Major difference when earth-centered
- IERS: International Terrestrial Reference Frame
What is a datum?

- Geodetic datums define the size and shape of the earth and the origin and orientation of coordinate systems used in mapping
- Hundreds of different datums have been used
- Datums have evolved from a spherical earth to ellipsoidal models derived from satellite measurements

Closing in on a value \( e = 1 - \frac{1}{f} \)

Earth as the WGS84 ellipsoid

For the WGS84:

\[
a = 6,378.137
\]

\[
b = 6,356.752.3
\]

\[
f = 1 - \frac{b}{a}
\]

Figure 5.3 The ellipsoid. The long axis is the major axis, the short the minor axis. Half of each of these lengths is used to calculate the flattening of the ellipsoid.

Datums matter

I'm 5ft.10" I'm 10ft.5"
Datum

- While cartography, surveying, navigation, and astronomy all make use of geodetic datums, the science of geodesy is central.
- Different nations and agencies use different datums as the basis for coordinate systems used in geographic information systems, precise positioning systems, and navigation systems.
- Referencing geodetic coordinates to the wrong datum can result in position errors of hundreds of meters.

Earth models and datums

The datum and the geoid

- An ellipsoid gives the base elevation for mapping, called a datum.
- Examples are NAD27 and NAD83.
- The geoid is a figure that adjusts the best ellipsoid and the variation of gravity locally.
- It is the most accurate, and is used more in geodesy than GIS and cartography.
- Geoids are dynamic!
Map scale

- Map scale is based on the representative fraction, the ratio of a distance on the map to the same distance on the ground.
- Most maps in GIS fall between 1:1 million and 1:1000.
- A GIS is scale-less because maps can be enlarged and reduced and plotted at many scales other than that of the original data.
- To compare or edge-match maps in a GIS, both maps MUST be at the same scale and have a common extent.
- The metric system is far easier to use for GIS work.

Why scale is an issue

Scale and accuracy

Degrees to 6 decimal places
1 degree approx 111,111m --- 0.000001 degree=11cm
Scale of a baseball earth

- Baseball circumference = 226 mm
- Earth circumference approx 40 million meters
- RF is : 1:177 million

Geographic coordinates—latitude and longitude

The American Meridian

The International Meridian Conference (1884: Washington DC)

“That it is the opinion of this Congress that it is desirable to adopt a single prime meridian for all nations, in place of the multiplicity of initial meridians which now exist.”

“That the Conference proposes to the Governments here represented the adoption of the meridian passing through the center of the transit instrument at the Observatory of Greenwich as the initial meridian for longitude.”

“That from this meridian longitude shall be counted in two directions up to 180 degrees, east longitude being plus and west longitude minus.”
The Prime Meridian (1884)

Remember: datum changes location

104m East of the Observatory

Greenwich observatory
Geographic coordinates

- Geographic coordinates are the earth’s latitude and longitude system, ranging from 90 degrees south to 90 degrees north in latitude and 180 degrees west to 180 degrees east in longitude.
- A line with a constant latitude running east to west is called a parallel.
- A line with constant longitude running from the north pole to the south pole is called a meridian.
- The zero-longitude meridian is called the prime meridian and passes through Greenwich, England.
- A grid of parallels and meridians shown as lines on a map is called a graticule.

Geographic coordinates as data

Map projections

- A transformation of the spherical or ellipsoidal earth onto a flat map is called a map projection.
- The map projection can be onto a flat surface or a surface that can be made flat by cutting, such as a cylinder or a cone.
- If the globe, after scaling, cuts the surface, the projection is called secant.
- Lines where the cuts take place or where the surface touches the globe have no projection distortion.
Map Projections (ctd)

- Projections can be based on axes parallel to the earth's rotation axis (equatorial), at 90 degrees to it (transverse), or at any other angle (oblique)
- A projection that preserves the shape of features across the map is called conformal
- A projection that preserves the area of a feature across the map is called equal area or equivalent
- No flat map can be both equivalent and conformal. Most fall between the two as compromises
- To compare or edge-match maps in a GIS, both maps MUST be in the same projection

No flat map can be both equivalent and conformal
A coordinate system is a standardized method for assigning codes to locations so that locations can be found using the codes alone.

- Standardized coordinate systems use absolute locations.
- A map captured in the units of the paper sheet on which it is printed is based on relative locations or map millimeters, we want earth coordinates.
- In a coordinate system, the x-direction value is the *easting* and the y-direction value is the *northing*.
- Most systems make both values positive.

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Example, CN Tower in Toronto:
- 630084E; 4833438N 17N

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The advantage of the transverse Mercator projection.
Universal Polar Stereographic (UPS) Coordinate Systems for the US

- Some standard coordinate systems used in the United States are
  - geographic coordinates
  - universal transverse Mercator system
  - military grid/MGRS/National grid
  - state plane
- To compare or edge-match maps in a GIS, both maps MUST be in the same coordinate system

Military Grid Coordinates

UTM zones/MGRS grid cell designators in the USA
USMG: Grid cell designators and 100,000m cells

USMG WGS84 / National Grid (NAD83)

State Plane Coordinates

Zones:
Lambert conformal conic vs. transverse Mercator

NAD 92 Unchanged NAD 83
NAD 83 Changes
State plane for California

Coordinate examples

- \(238,479\) mE; \(3,811,950\) mN; \(11, N\)
- \(11SKU3847911950\)
- \(N 34°24'57.24" W 119°50'42.9"\)
- \(603153 1830382 CA 5\)

National map viewer: Buchanan 1930

GIS minimum capability

- A GIS package should be able to move and convert between:
  - map projections
  - coordinate systems
  - datums
  - ellipsoids
Projection metadata

PROJCS[“Teale_Albers”,GEOGCS[“GCS_North_American_1927”,DATUM [“D_North_American_1927”,SPHEROID[“Clarke_1866”,6378206.4, 294.9786982]],PRIMEM[“Greenwich”,0],UNIT[“Degree”, 0.017453292519943295]],PROJECTION[“Albers”],PARAMETER [“False_Easting”,0],PARAMETER[“False_Northing”,-4000000], PARAMETER[“Central_Meridian”,-120],PARAMETER [“Standard_Parallel_1”,34.0],PARAMETER[“Standard_Parallel_2”,-40.5], PARAMETER[“Latitude_Of_Origin”,0],UNIT[“Meter”,1]]

Geographic information

- Characteristics
  - volume
  - dimensionality
  - continuity

Building complex features

- Simple geographic features can be used to build more complex ones.
- Areas are made up of lines which are made up of points represented by their coordinates.
- Areas = {Lines} = {Points}

Areas are lines are points are coordinates

Figure 2: Areas are made up of lines which are made up of points represented by their coordinates.
Example

Properties of Features

- size
- distribution
- pattern
- contiguity
- neighborhood
- shape
- scale
- orientation

Basic properties of geographic features

GIS Analysis

- Much of GIS analysis and description consists of investigating the
  - properties of geographic features and
  - determining the relationships among them
- Shape, distribution, size, etc.
- Adjacency, proximity, intersection
Coming next....

Maps as Numbers